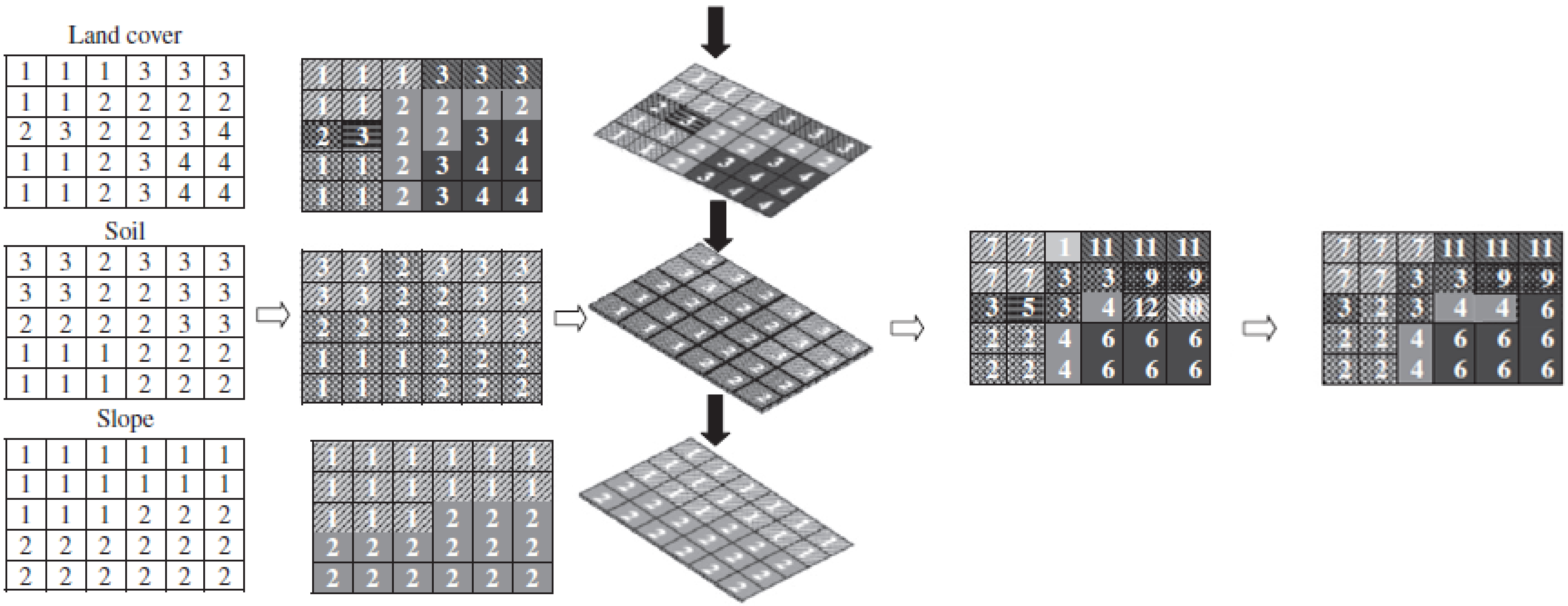


Minimizing errors in HRU aggregation

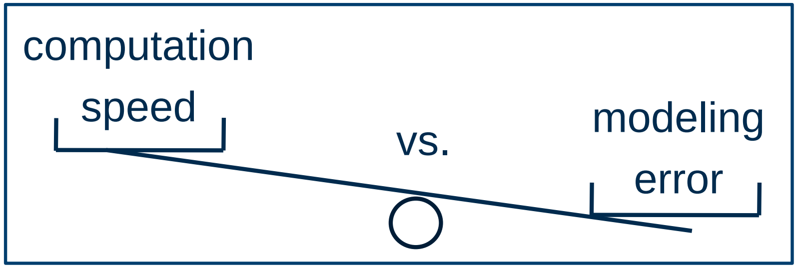
Michael Strauch, Robert Otto, Martin Volk

2014 International SWAT Conference
Porto de Galinhas, July 30 – August 1, 2014

HELMHOLTZ
ZENTRUM FÜR
UMWELTFORSCHUNG
UFZ

HRU aggregation

- a necessary evil for efficient simulations
- two ways for reducing complexity

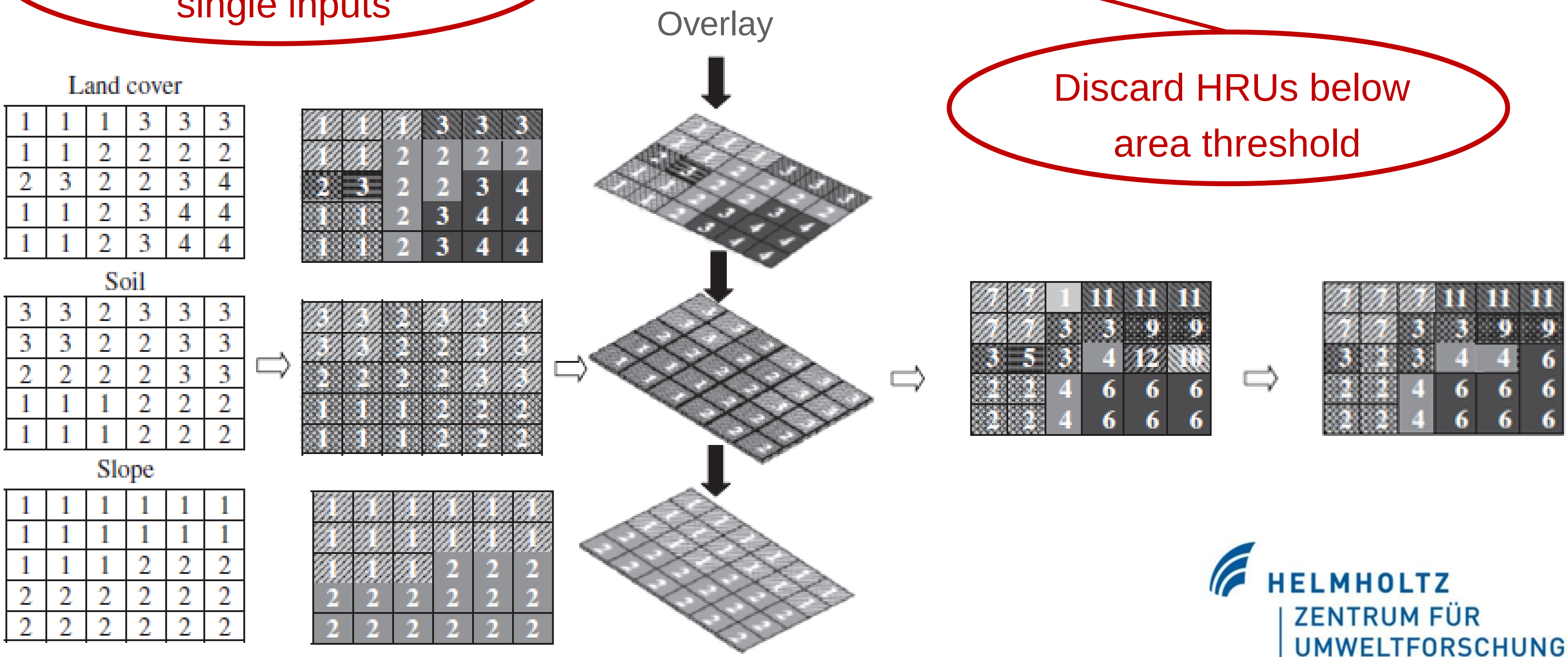


1

Generalize (reclassify) single inputs

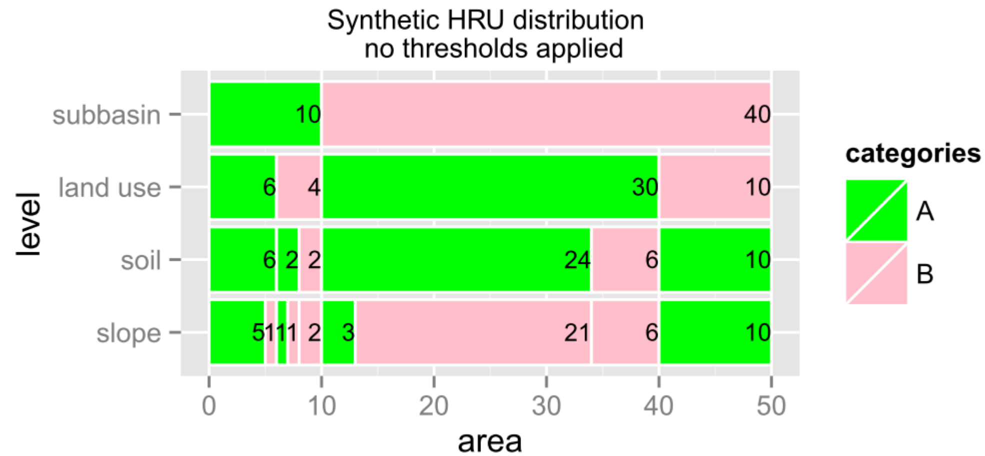
2

Discard HRUs below area threshold

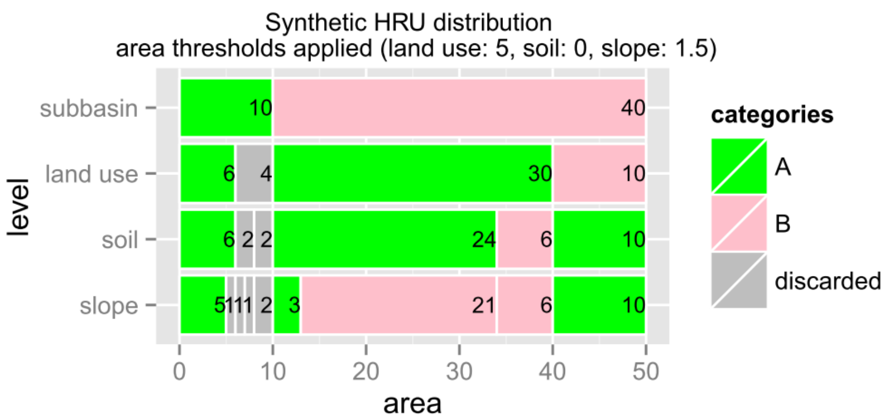


HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

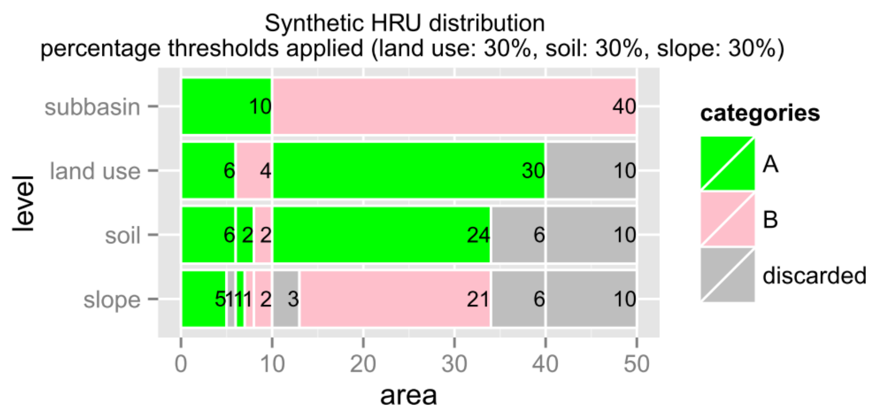
HRU definition in ArcSWAT – theoretical example



a) absolute area



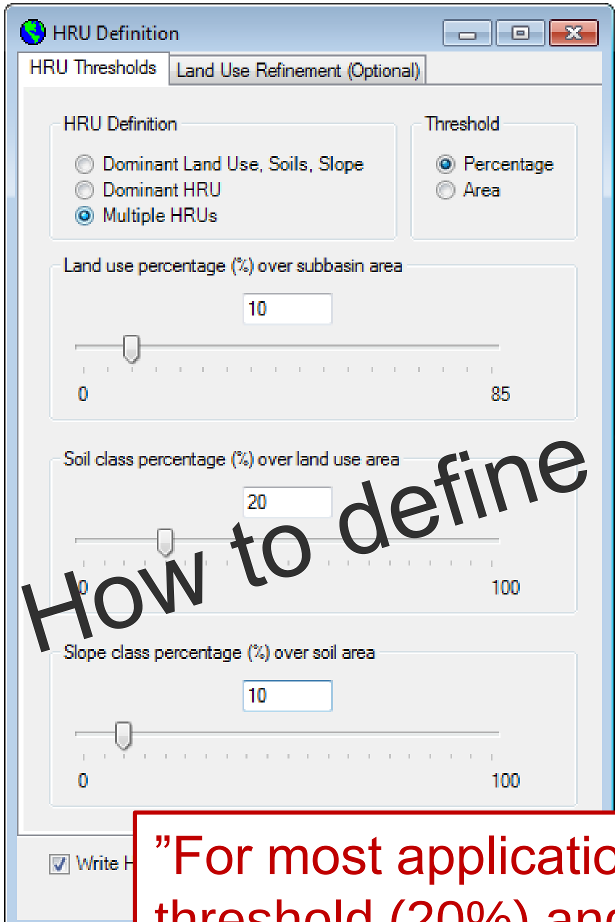
b) percentage area



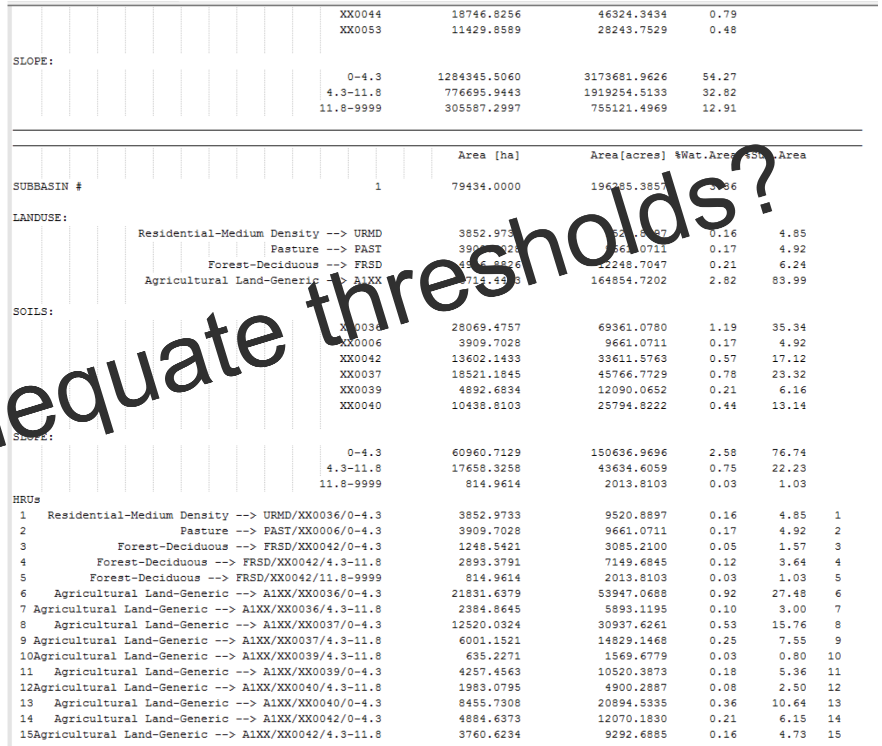
HELMHOLTZ
ZENTRUM FÜR
UMWELTFORSCHUNG
UFZ

HRU definition in ArcSWAT

ArcSwat



example output



	XX0044	18746.8256	46324.3434	0.79		
	XX0053	11429.8589	28243.7529	0.48		
SLOPE:						
	0-4.3	1284345.5060	3173681.9626	54.27		
	4.3-11.8	776695.9443	1919254.5133	32.82		
	11.8-9999	305587.2997	755121.4969	12.91		
		Area [ha]	Area[acres]	%Wat.Area	[illegible]	
SUBBASIN #	1	79434.0000	[illegible]	[illegible]		
LANDUSE:						
	Residential-Medium Density --> URMD	[illegible]	[illegible]	0.16	4.85	
	Pasture --> PAST	[illegible]	[illegible]	0.17	4.92	
	Forest-Deciduous --> FRSD	[illegible]	[illegible]	0.21	6.24	
	Agricultural Land-Generic --> A1XX	[illegible]	164854.7202	2.82	83.99	
SOILS:						
	[illegible]	28069.4757	69361.0780	1.19	35.34	
	XX0006	3909.7028	9661.0711	0.17	4.92	
	XX0042	13602.1433	33611.5763	0.57	17.12	
	XX0037	18521.1845	45766.7729	0.78	23.32	
	XX0039	4892.6834	12090.0652	0.21	6.16	
	XX0040	10438.8103	25794.8222	0.44	13.14	
[illegible]						
	0-4.3	60960.7129	150636.9696	2.58	76.74	
	4.3-11.8	17658.3258	43634.6059	0.75	22.23	
	11.8-9999	814.9614	2013.8103	0.03	1.03	
HRUs						
1	Residential-Medium Density --> URMD/XX0036/0-4.3	3852.9733	9520.8897	0.16	4.85	1
2	Pasture --> PAST/XX0006/0-4.3	3909.7028	9661.0711	0.17	4.92	2
3	Forest-Deciduous --> FRSD/XX0042/0-4.3	1248.5421	3085.2100	0.05	1.57	3
4	Forest-Deciduous --> FRSD/XX0042/4.3-11.8	2893.3791	7149.6845	0.12	3.64	4
5	Forest-Deciduous --> FRSD/XX0042/11.8-9999	814.9614	2013.8103	0.03	1.03	5
6	Agricultural Land-Generic --> A1XX/XX0036/0-4.3	21831.6379	53947.0688	0.92	27.48	6
7	Agricultural Land-Generic --> A1XX/XX0036/4.3-11.8	2384.8645	5893.1195	0.10	3.00	7
8	Agricultural Land-Generic --> A1XX/XX0037/0-4.3	12520.0324	30937.6261	0.53	15.76	8
9	Agricultural Land-Generic --> A1XX/XX0037/4.3-11.8	6001.1521	14829.1468	0.25	7.55	9
10	Agricultural Land-Generic --> A1XX/XX0039/4.3-11.8	635.2271	1569.6779	0.03	0.80	10
11	Agricultural Land-Generic --> A1XX/XX0039/0-4.3	4257.4563	10520.3873	0.18	5.36	11
12	Agricultural Land-Generic --> A1XX/XX0040/4.3-11.8	1983.0795	4900.2887	0.08	2.50	12
13	Agricultural Land-Generic --> A1XX/XX0040/0-4.3	8455.7308	20894.5335	0.36	10.64	13
14	Agricultural Land-Generic --> A1XX/XX0042/0-4.3	4884.6373	12070.1830	0.21	6.15	14
15	Agricultural Land-Generic --> A1XX/XX0042/4.3-11.8	3760.6234	9292.6885	0.16	4.73	15

How to define adequate thresholds?

”For most applications, the default settings for land use threshold (20%) and soil threshold (10%) and slope threshold (20%) are adequate.” (Winchell et al., 2007, p. 126)

UMWELTFORSCHUNG UFZ

Minimizing the aggregation error using R

You simply need the *Full HRU table* generated from ArcSWAT

Table

hrus

OID *	SUBBASIN *	ARSUB	LANDUSE	ARLU	SOIL	ARSO	SLP	ARSLP	SLOPE	UNIQUECOMB	HRU_ID	HRU_GIS
420	76	3493797.677604	RNGE	1522435.270746	PE52	273096.551882	0-15.45	119163.134603	9.122732	76_RNGE_PE52_0-15.45	420	000760015
421	76	3493797.677604	RNGE	1522435.270746	PE52	273096.551882	15.45-43.54	153933.417279	25.671921	76_RNGE_PE52_15.45-43.54	421	000760016
422	76	3493797.677604	RNGE	1522435.270746	PE53	172976.854437	0-15.45	172976.854437	7.956806	76_RNGE_PE53_0-15.45	422	000760017
423	76	3493797.677604	RNGE	1522435.270746	PE54	528817.545667	15.45-43.54	321808.514489	26.727308	76_RNGE_PE54_15.45-43.54	423	000760018
424	76	3493797.677604	RNGE	1522435.270746	PE54	528817.545667	0-15.45	207009.031178	9.140409	76_RNGE_PE54_0-15.45	424	000760019
425	76	3493797.677604	RNGE	1522435.270746	PE55	375618.211774	15.45-43.54	375618.211774	27.959536	76_RNGE_PE55_15.45-43.54	425	000760020
426	76	3493797.677604	RNGE	1522435.270746	PE65	53555.228567	15.45-43.54	53555.228567	28.941126	76_RNGE_PE65_15.45-43.54	426	000760021
427	76	3493797.677604	RNGE	1522435.270746	PE78	118370.878419	15.45-43.54	118370.878419	28.321695	76_RNGE_PE78_15.45-43.54	427	000760022

as input for an R-script, where you can

- Choose the method (ha or %) and the range for a threshold application
- for each threshold combination (land use / soil / slope)…
  …define HRUs (as ArcSWAT would do)
  …and calculate the Relative Total Error (RTE) compared to the full HRU distribution
- plot and analyze results

Relative Total Error

$$RTE = \frac{1}{n_j \sum_{ijk} y_{ref_{ijk}}} \sum_{jk}(|y_{agg_{ijk}} - y_{ref_{ijk}}|)$$

y = HRU area (agg and ref denoting aggregated and reference, respectively)
i = subbasin index 1,…,n_i
j = HRC index 1,…,n_j (Hydrologic Response Criterion,
e.g. 1 = land use, 2 = soils, 3 = slope)
k = HRC category index 1,…,n_{ijk} (i.e. different land use, soil, and slope classes,
k depends on HRC and subbasin)

RTE is the sum of absolute residuals of the land use, soil, and slope distributions between an aggregated solution and the full HRU distribution normalized by the full HRU area distribution.
RTE can range from 0 to 1 (or from 0 to 100%).

HELMHOLTZ
| ZENTRUM FÜR

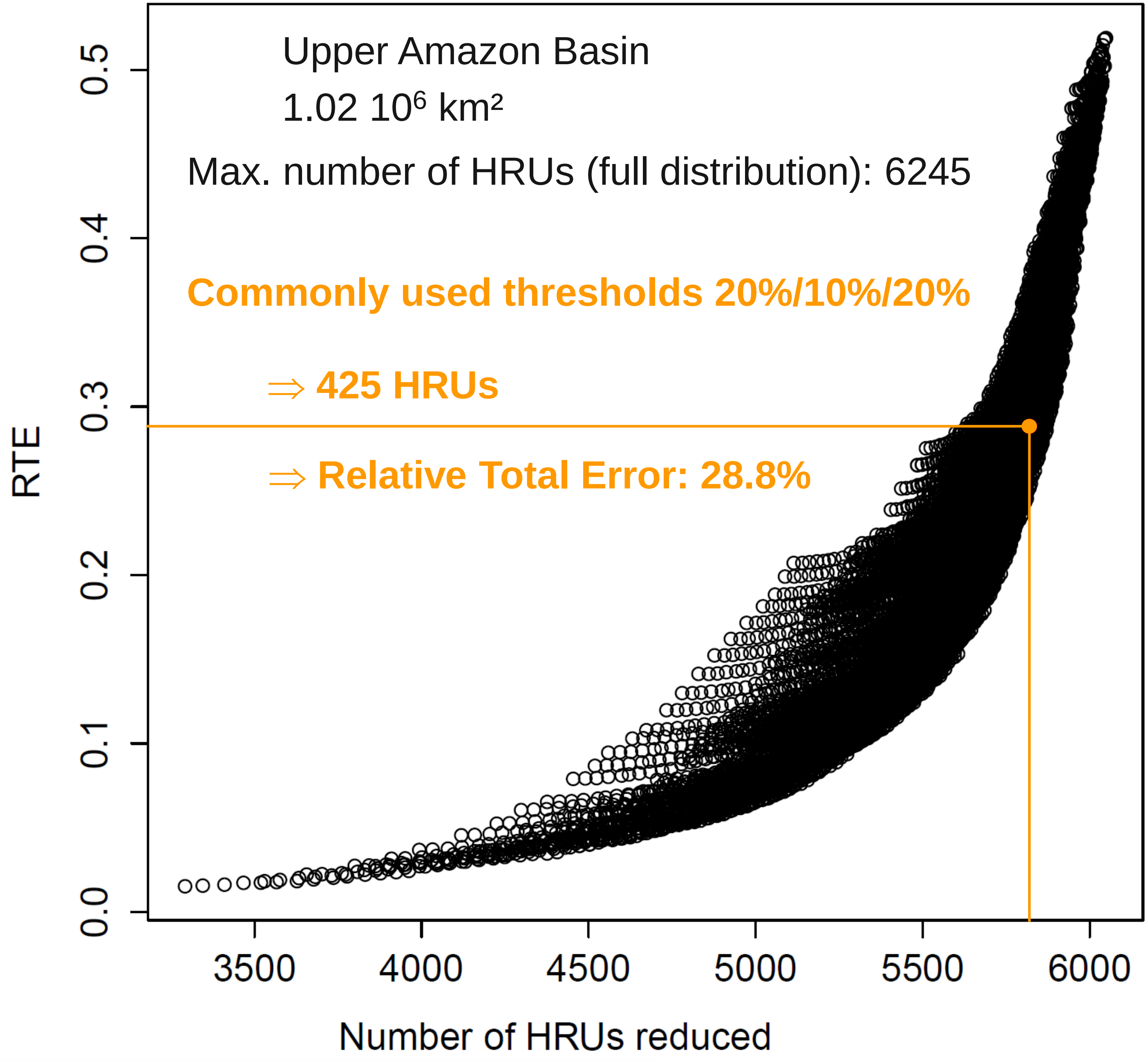
Results

(for 15,625 solutions)

Method:
Percentage

Threshold range:
1 … 25%

Threshold step:
1%



Results

(for 15,625 solutions)

Method:
Percentage

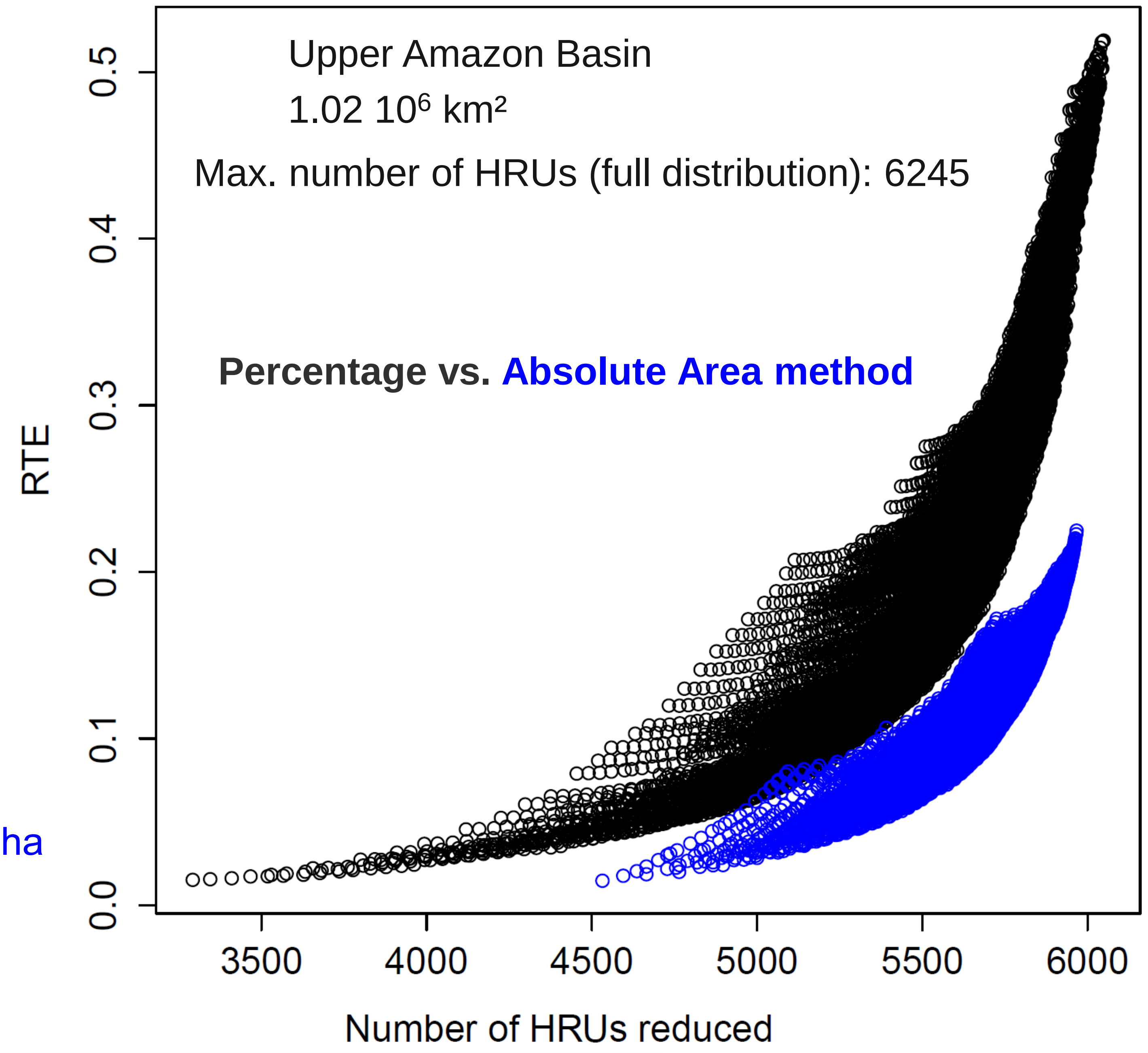
Threshold range:
1 … 25%

Step: 1%

Method:
Area (ha)

Threshold range:
5.000 … 125.000 ha

Step: 5.000 ha



Results

(for 15,625 solutions)

Method:
Percentage

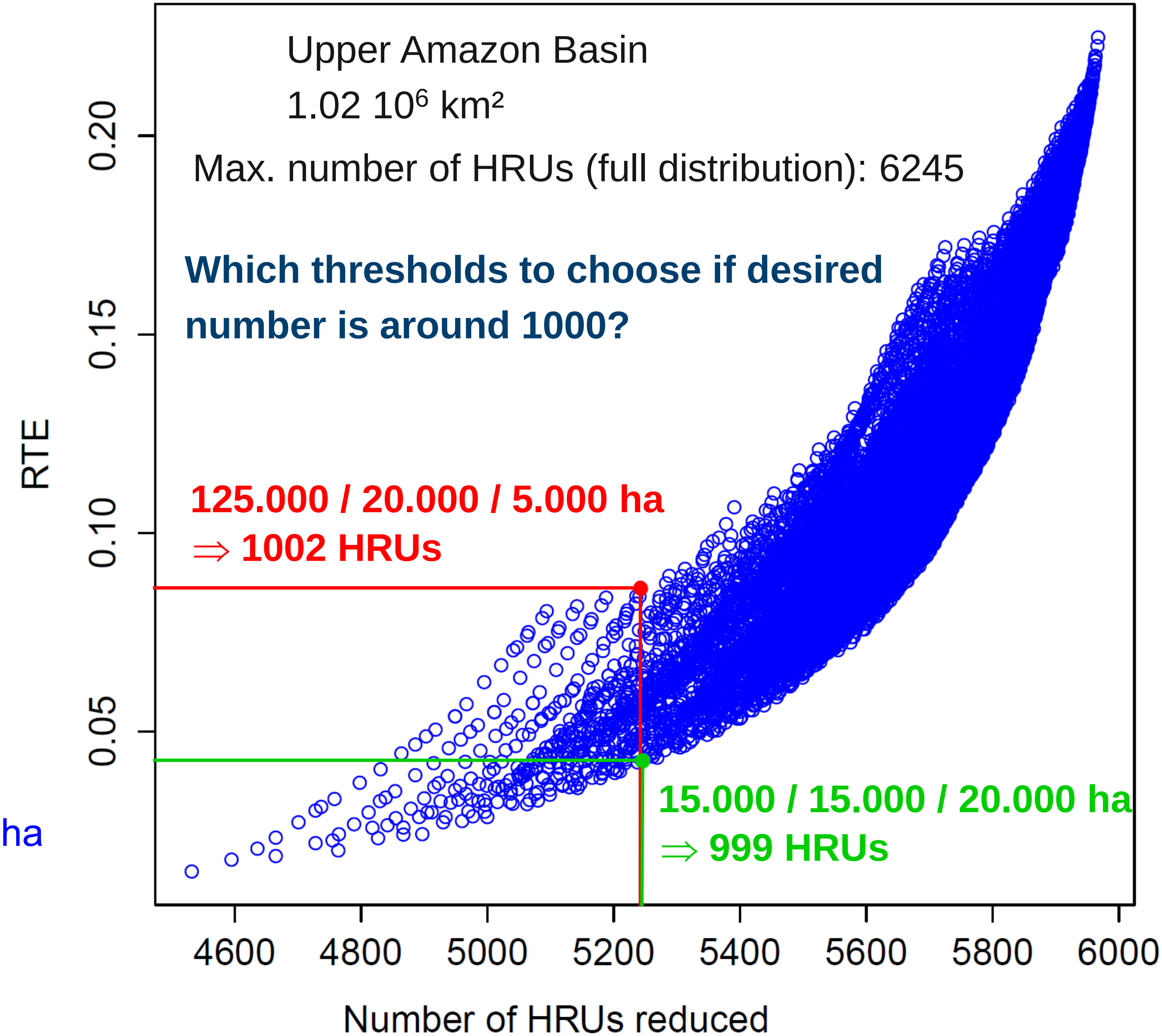
Threshold range:
1 … 25%

Step: 1%

Method:
Area (ha)

Threshold range:
5.000 … 125.000 ha

Step: 5.000 ha

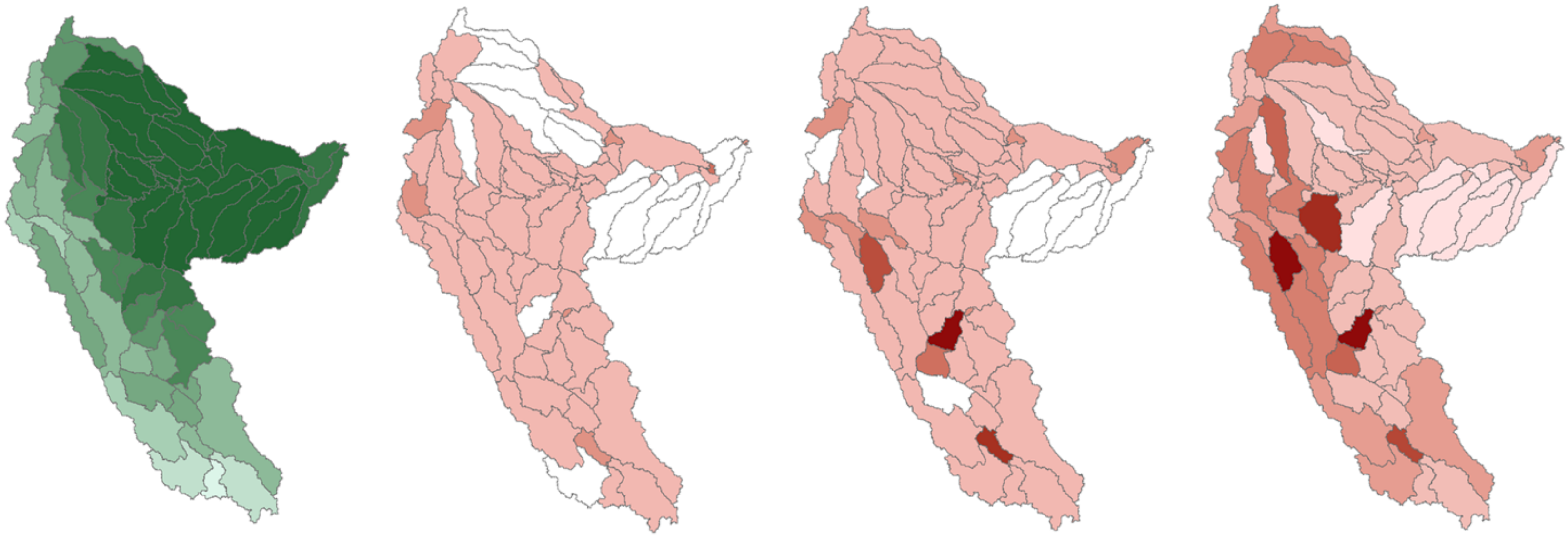


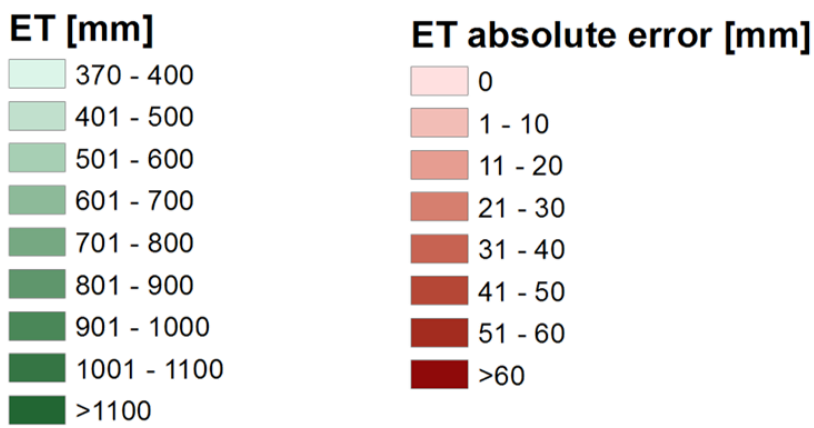
Full HRU distribution (= 6245 HRUs)

Option 1
15k/15k/20k ha
(= 999 HRUs)

Option 2
125k/20k/5k ha
(= 1002 HRUs)

Option 3
20/10/20%
(= 425 HRUs)

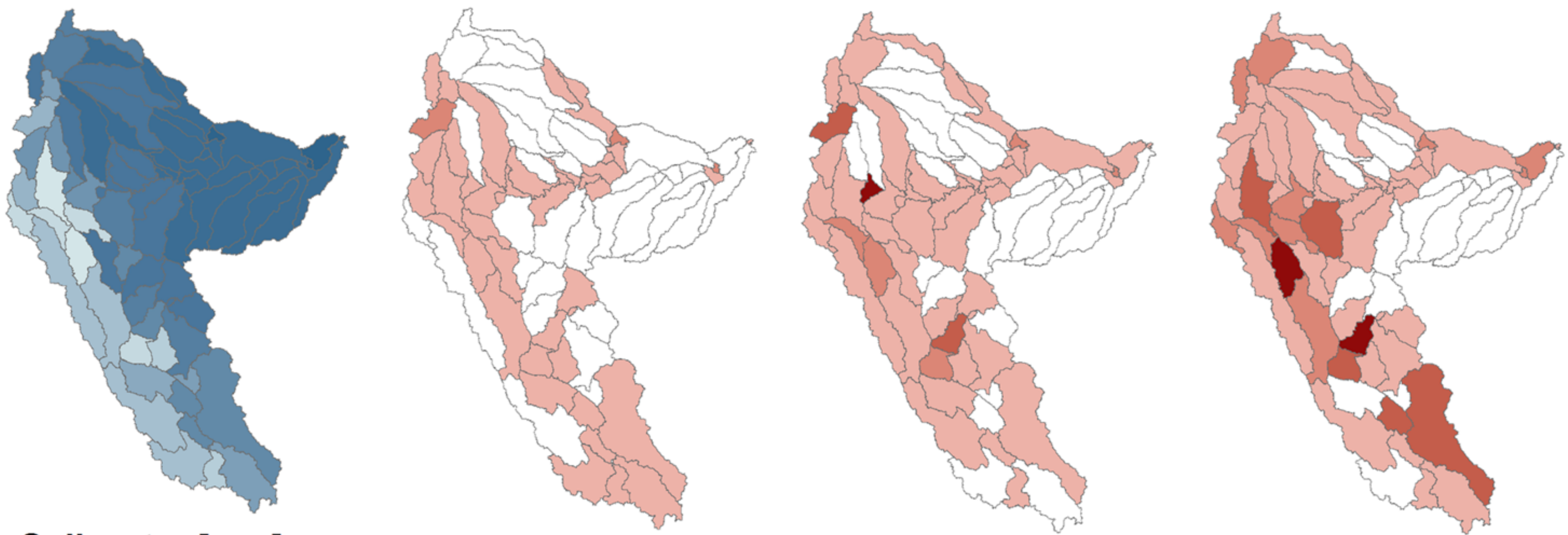




Effects of HRU threshold application on SWAT outputs (uncalibrated model)

HELMHOLTZ
| ZENTRUM FÜR

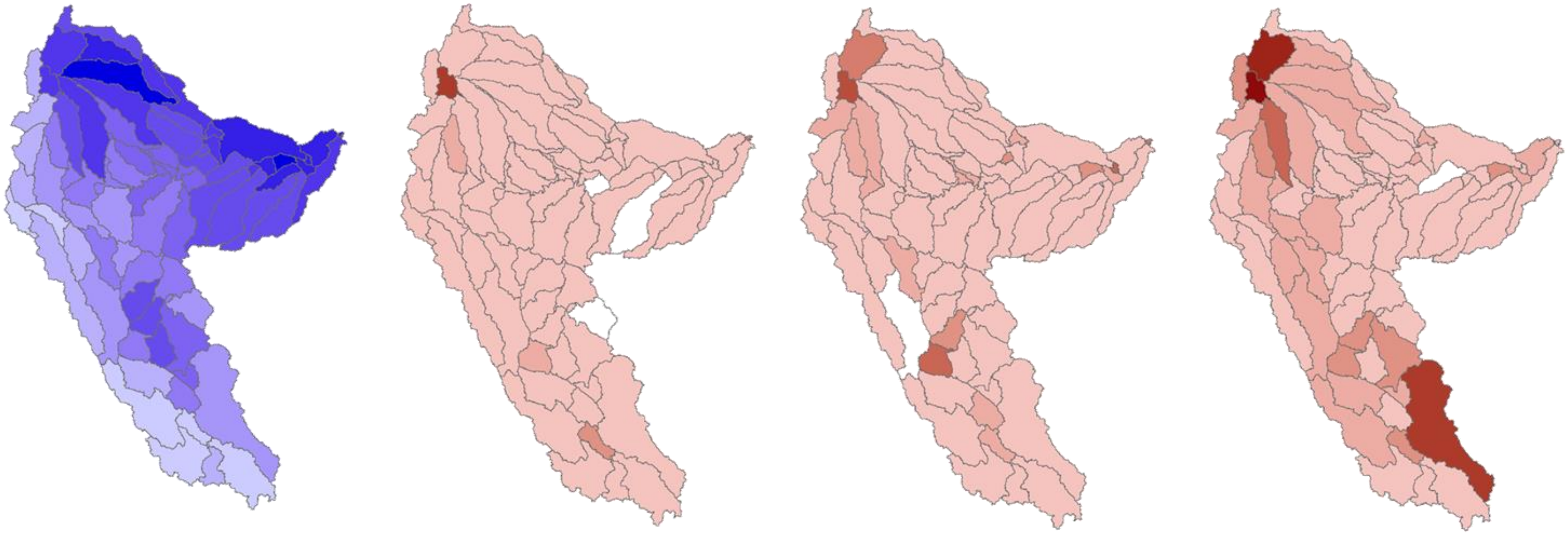
Full HRU distribution (= 6245 HRUs)	Option 1 15k/15k/20k ha (= 999 HRUs)	Option 2 125k/20k/5k ha (= 1002 HRUs)	Option 3 20/10/20% (= 425 HRUs)



Effects of HRU threshold application on SWAT outputs (uncalibrated model)

HELMHOLTZ | ZENTRUM FÜR

Full HRU distribution (= 6245 HRUs)	Option 1 15k/15k/20k ha (= 999 HRUs)	Option 2 125k/20k/5k ha (= 1002 HRUs)	Option 3 20/10/20% (= 425 HRUs)



Groundwater flow [mm]

- 1 - 200
- 201 - 400
- 401 - 600
- 601 - 800
- 801 - 1000
- 1001 - 1200
- 1201 - 1400
- 1401 - 1600
- >1600

Absolute error [mm]

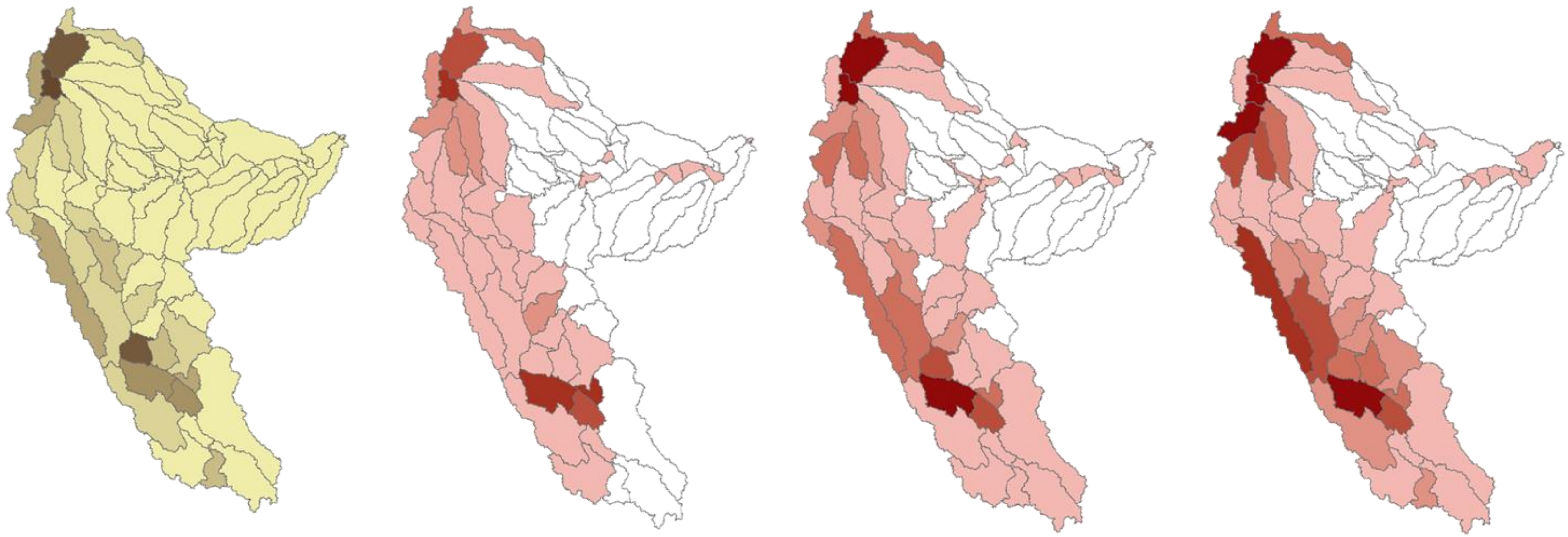
- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- 101 - 120
- 121 - 140
- 141 - 160
- >160

Effects of HRU threshold application on SWAT outputs (uncalibrated model)

HELMHOLTZ | ZENTRUM FÜR

Full HRU distribution (= 6245 HRUs)

Option 1	Option 2	Option 3
15k/15k/20k ha	125k/20k/5k ha	20/10/20%
(= 999 HRUs)	(= 1002 HRUs)	(= 425 HRUs)



Sediment yield [t/ha]

- 0 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- 101 - 120
- 121 - 140
- 141 - 160
- >160

Absolute error [t/ha]

- 0
- 1 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- >50

Effects of HRU threshold application on SWAT outputs (uncalibrated model)

Summary / conclusion

- **HRU aggregation** is often **necessary** for efficient simulations **but causes model errors**

⇒ i.e., errors in the spatial distribution of land use, soil, and slope which in turn cause errors in model outputs

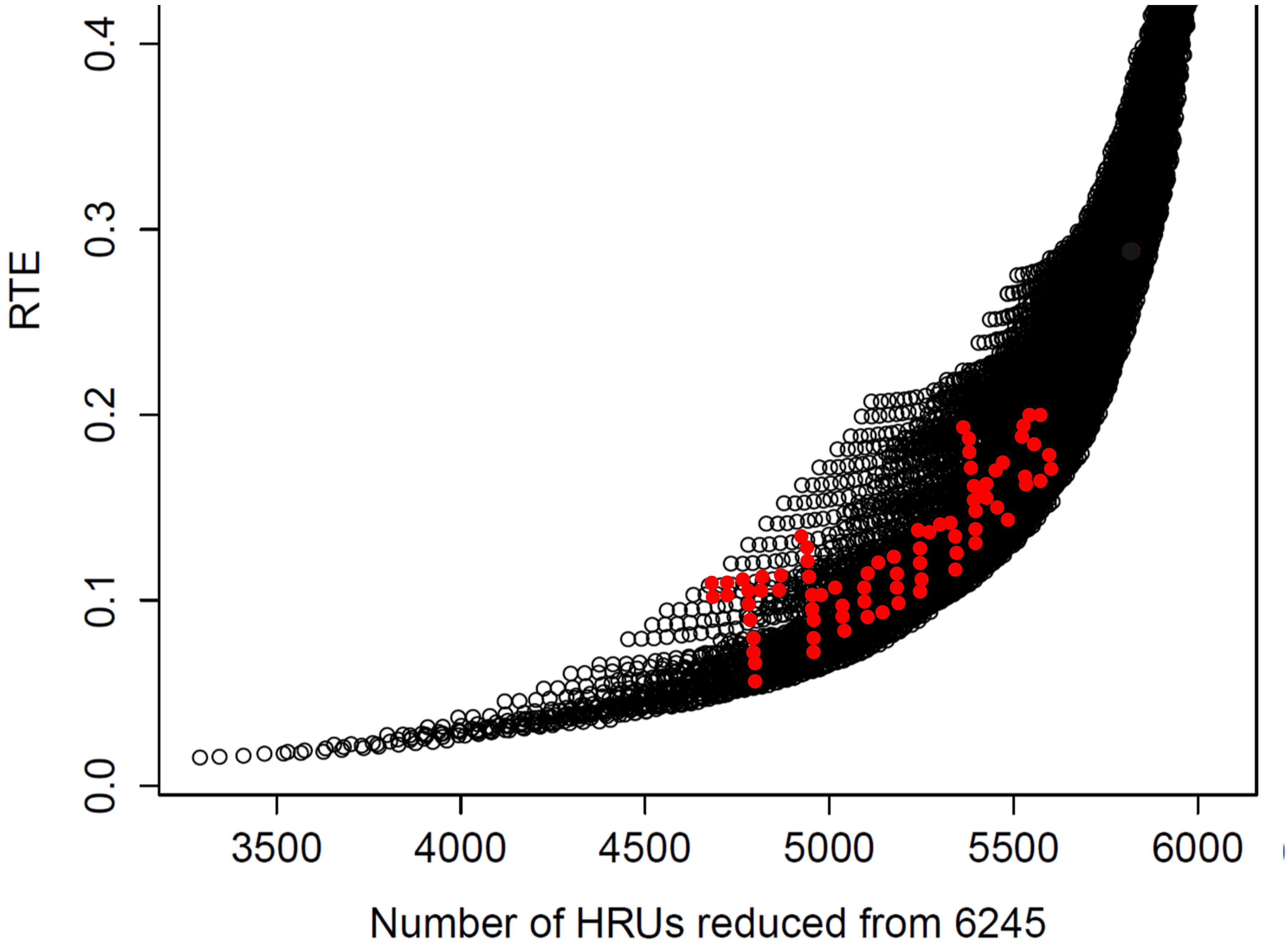
- **So far no reasonable guideline** for selecting HRU thresholds

- **R-Script to efficiently analyze thousands of threshold combinations**

⇒ R-Script **allows identification of best thresholds** given a desired number of HRUs (or given a maximum tolerable error)

⇒ **Should be useful for the model community** (as tool provided on SWAT homepage or even implemented into ArcSWAT?)

HELMHOLTZ
| ZENTRUM FÜR


RTE
0.0
0.1
0.2
0.3
0.4
3500
4000
4500
5000
5500
6000
Number of HRUs reduced from 6245
Thanks

Additional slides

Reducing complexity (i.e. the number of HRUs)

1. **Generalization of single input data**
   - Aggregation based on cluster analysis (e.g. aggregate hydrologically similar soil types)
   - Best practice, but difficult, requires expert knowledge

2. **HRU aggregation (discard small HRUs)**
   - HRUs with area below threshold are discarded
   - Remaining HRUs „blow up“ proportionally to „fill gaps“
   - Common practice (e.g. thresholds in ArcSWAT‘s HRU definition), easy, but can result in large errors (compared to „true“ distribution of landscape characteristics)

HELMHOLTZ
ZENTRUM FÜR
UMWELTFORSCHUNG
UFZ